## **Public Health Focus**

## \* Reducing Sodium Intake in Children: A Public Health Investment

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The antecedents of elevated blood pressure (BP) and its major consequences (cardiovascular disease and stroke) begin in childhood. Higher levels of BP early in life track into adulthood and are associated with subclinical target organ damage in children and adults. Diet behaviors, including the choice of high sodium containing foods, are established during childhood. On average, children, ages 2-19, consume more than 3,100 mg of sodium per day, with substantially greater sodium intakes in boys than girls. Importantly, studies show that lowering sodium intake in children lowers blood pressure. In view of this evidence, US Dietary Guidelines recommend a reduced sodium intake in children. Current federal nutrition standards include a step-wise

reduction in the sodium levels of school meals. The ultimate goal is to help children achieve daily sodium intakes that do not exceed upper levels recommended by the Institute of Medicine and the Dietary Guidelines for Americans. In summary, available data are sufficiently strong to recommend a lower sodium intake beginning in early in life as an effective and well-tolerated approach to reducing BP in children. Current efforts to weaken nutrition standards for school meals undermine an effective strategy aimed at improving the health of our children and our nation. *J Clin Hypertens (Greenwich)*. 2015;17:657–662. © 2015 The Authors. *The Journal of Clinical Hypertension* Published by Wiley Periodicals, Inc.

While the clinical manifestations of elevated blood pressure (BP) occur predominantly in adults, the antecedents of chronic diseases (obesity, diabetes, atherosclerotic heart disease, and stroke) begin in childhood. Hence, the contemporary approach to halting the epidemic of cardiovascular disease (CVD) emphasizes prevention of risk factors, ideally beginning very early in life among children. Although prevention-oriented strategies are often tested in studies conducted in adults, interventions aimed at reducing BP over the lifespan are likely to have a greater impact if started early in childhood when eating habits are formed and before asymptomatic, preclinical abnormalities begin.

Currently, efforts are underway to weaken nutrition standards for school food programs, including efforts to repeal targets for sodium. This paper reviews evidence documenting the benefits of strategies that lower sodium intake in children and documenting that proposed reductions in sodium are both feasible and acceptable.

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Manuscript received: May 21, 2015; accepted: May 29, 2015

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### THE CURRENT POLITICAL LANDSCAPE

Through two major programs (the School Breakfast Program<sup>2</sup> and the National School Lunch Program<sup>3</sup>), federal nutrition standards have a broad impact on the food served to children. Each school day, these programs serve more than 12 million and 31 million children, respectively. These programs are currently operating under the Healthy, Hunger-Free Kids Act (HHFKA).<sup>4</sup> Passed in 2010, the Act marked the first time in a generation that nutrition standards for foods in schools were updated to reflect the latest nutrition science.

Because children who eat school meals can consume 50% or more of their daily calories at school,<sup>5</sup> it is important that foods available in schools meet nutrient requirements and promote the development of life-long healthy eating habits. The nutrition standards in the HHFKA limit calories, saturated and *trans* fats, and added sugars while increasing fruits and vegetables and substituting whole grains for refined grains. The Act also includes sodium targets and set out a 12-year timeline for lowering sodium over three phases, based on recommendations from the Institute of Medicine (IOM) (Table).<sup>5</sup> The planned reductions would lower the baseline sodium levels of approximately 1300 mg to 1500 mg per lunch<sup>6</sup> to levels consistent with the Dietary Guidelines for Americans.

The phased reductions are projected to reduce the sodium content of school meals by approximately 25% to 50% by 2022. It is also projected that sodium intake among US school-aged children (defined as ages 6–18)

TABLE. Timelines for Sodium Reduction in School Lunch and Breakfast							
Lunch Sodium Reduction Timeline				Breakfast Sodium Reduction Timeline			
Grade Group	Target 1: School Year 2014–2015, mg	Target 2: School Year 2017–2018, mg	Target 3: School Year 2022–2023, mg	Grade Group	Target 1: School Year 2014–2015, mg	Target 2: School Year 2017–2018, mg	Target 3: School Year 2022–2023, mg
K-5 6-8 9-12	≤1230 ≤1360 ≤1420	≤935 ≤1035 ≤1080	≤640 ≤710 ≤740	K-5 6-8 9-12	≤540 ≤600 ≤640	≤485 ≤535 ≤570	≤430 ≤470 ≤500

will be reduced by an average of about 75 mg to 150 mg per day and about 220 mg to 440 mg on days children consume school meals.<sup>7</sup>

The School Nutrition Association has voiced concerns that school food services will have difficulty in procuring foods that meet the sodium standards. As a result, Congress included a provision in a December 2014 omnibus spending bill that stated "sodium standards cannot be reduced below Target 1 until the latest scientific research establishes the reduction is beneficial for children."8 Ongoing efforts by some stakeholders and their representatives in Congress are attempting to weaken the sodium standards, with some calling for their complete elimination. However, the concern about difficulty in procuring foods that meet the sodium targets is not consistent with the USDA's May announcement that 95% of schools are in compliance with the new nutrition standards. Furthermore, in a national survey of food service administrators and staff, 70% of respondents reported that students like the new lunches.1

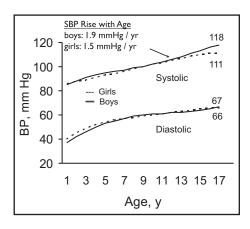
By early 2016, the federal child nutrition programs will be reauthorized, including school meal programs. Evidence from a broad array of strong scientific studies supports the current recommendations for sodium reduction in the HHFKA.

# SCIENTIFIC ISSUES RELATED TO BP AND SODIUM INTAKE IN CHILDREN

### Epidemiology of Elevated BP

At birth, BP is low (approximately 60/40 mm Hg) and increases steadily in virtually all children until adolescence (Figure 1).<sup>11</sup> The rise in BP with age is similar in boys and girls, until early adolescence when the rise in systolic BP is significantly faster in boys than the corresponding rise in girls. It is important to emphasize that the overall average rate of rise in BP (~1.9 mm Hg per year in boys and ~1.5 mm Hg per year in girls), while usual, may not be normal. Because of the agerelated rise in BP in children and subsequently in adults, 90% of US adults will develop hypertension over their lifetime.<sup>12</sup>

Adverse clinical outcomes from elevated BP rarely occur in children or adolescents, but there is considerable evidence to support an association between higher levels of BP in children and BP-related CVD in adults.



**FIGURE 1.** Mean systolic and diastolic blood pressure (BP) in US children (50th percentile for height), ages 1 to 17 years. <sup>11</sup>

First, childhood BP tracks into adulthood, with reported tracking correlations of 0.38 for systolic BP and 0.28 for diastolic BP. <sup>13</sup> Moreover, BP tracking has been shown to occur in concert with tracking of lipids and BMI, <sup>14</sup> magnifying the potential adverse impact of childhood BP on development of CVD.

Second, BP levels are associated with subclinical CVD during childhood. BP is strongly associated with carotid intimal-medial thickness. <sup>15,16</sup> pulse wave velocity, <sup>17</sup> and left ventricular mass index <sup>16,18</sup> in adolescents. Importantly, there is direct longitudinal evidence that elevated BP in adolescents predicts pathologic changes associated with CVD. Both the Bogalusa Heart Study <sup>19</sup> and the Pathobiologic Determinants of Atherosclerosis in Youth Study (PDAY) <sup>20</sup> documented a significant association between degree of atherosclerosis in the coronary arteries and levels of ante-mortem BP in youth who died during adolescence.

Third, childhood BP has been associated with a variety of subclinical cardiovascular findings in adults. Systolic BP in children, as early as age 6 years and continuing through age 18 years, is associated with carotid intimamedia thickness at age 33 to 42 years<sup>21</sup>; elevated BP at age 10 has predicted pulse wave velocity at age 40<sup>22</sup>; and childhood BP has been reported to be a significant independent predictor of coronary artery calcification.<sup>23,24</sup> In contrast, in those adults with elevated BP during childhood but reduced BP in adulthood, carotid intima-media thickness is not significantly different from levels found in individuals who never had elevated BP.<sup>25</sup>

These data support the introduction of intervention strategies early in life to maintain normal BP.

### Relationship of Sodium Intake and BP in Children

Reduced sodium intake lowers BP in children. A metaanalysis of 13 dietary trials in children (three trials in infants and 10 in older children) confirmed that modest reductions in sodium intake are associated with a reduction in BP.26 The adverse effect of sodium on BP begins at birth. A widening gap in BP between infants fed a low-sodium formula and infants fed a regularsodium formula was observed during the first 6 months of life in a trial conducted in the Netherlands, with significantly lower mean BP measured in the lowsodium group at the end of the trial.<sup>27</sup> Moreover, when these infants were restudied at 15 years of age, the group formerly on the low-sodium diet during infancy continued to have a significantly lower BP than the regular-formula control group, despite having been on a regular diet from age 6 months. 28 Thus, reducing sodium intake early in life may have a "programming" effect on future BP levels.

Studies in school children have used a variety of methods to test the sodium-BP relationship. In the 2-year Exeter-Andover Project,<sup>29</sup> it was possible to significantly reduce sodium by controlling the amount used in food preparation for students relying on the school for their meals. The result was a significant reduction in sodium intake in association with a significant reduction in BP. In a more recent school intervention study in China, grade school students and their families were trained to reduce sodium intake in their homes. Although sodium intake decreased significantly in comparison to a control group on a regular diet, the level of reduction did not have a significant impact on BP. 30 A 3-year trial in adolescents and their parents used an intensive education and reinforcement-maintenance program to reduce dietary sodium in a free-living population.<sup>31</sup> Despite personal counseling every 3 months and frequent phone counseling, the adolescent boys did not have a significant reduction in sodium intake or BP. In contrast, the girls were able to maintain reduced sodium intake compared with baseline and had a significant reduction in BP.

These data from studies in children suggest a variety of approaches to interrupting the ongoing high prevalence of hypertension and BP-related CVD. The findings that higher levels of BP are associated with subclinical target organ damage as early as childhood, track into adulthood, and predict subclinical target organ damage in adults strongly support the need to develop and implement strategies for reducing sodium intake in the first 2 decades of life. The relationship of decreased sodium intake to decreased BP in children suggests that an effective method for reducing dietary sodium may have a significant impact on lifetime reduction of BP and its adverse effects on morbidity and mortality. Further, there is evidence that sodium

reduction may be particularly effective in overweight children. <sup>32</sup>

## SODIUM INTAKE RECOMMENDATIONS MADE BY AUTHORITATIVE BODIES

Dietary Reference Intakes for Sodium From the IOM Recommended sodium intakes vary by age. For sodium, the IOM set the upper level (maximum intake) at 1500 mg/d, 1900 mg/d, 2200 mg/d, and 2300 mg/d for ages 1 to 3 years, 4 to 8 years, 9 to 13 years, and 14 to 18 years, respectively.<sup>33</sup>

## 2010 Dietary Guidelines for Americans and 2010 Dietary Guidelines Advisory Committee Report

The 2010 Dietary Guidelines for Americans recommended a target sodium level of 2300 mg/d for the general population and 1500 mg for persons who are 51 years and older and those of any age who are African American or have hypertension, diabetes, or chronic kidney disease.<sup>34</sup> It was estimated that the 1500-mg recommendation applies to about half of the US population, including children.<sup>35</sup> Although no specific targets for sodium intake in infants and children were specified, the 2010 Dietary Guidelines Advisory Committee report noted that sodium intake in infants and children is of concern because BP during childhood tracks over time and elevated BP in childhood results in significant cardiovascular dysfunction and pathology both earlier and later in life. The committee emphasized that taste preferences for salt, the major source of sodium in the diet, are established early and shaped by dietary exposure.

## 2015 Dietary Guidelines Advisory Committee Report

The 2015 Dietary Guidelines Advisory Committee did not directly address the issue of sodium intake for children. Rather, the 2015 report identified sodium as a nutrient overconsumed relative to the upper level of dietary reference intakes. They recommended a goal for the general population of <2300 mg dietary sodium per day or age-appropriate upper levels set by the IOM. The committee noted that sodium is ubiquitous in the food supply and for this reason suggested that to decrease intake toward recommended levels concerted efforts will be needed to reduce levels in commercially prepared and processed foods and encourage more food preparation at home, specifically using less salt. Finally, it was noted that more than any other nutrient, sodium intake undermines the Healthy Eating Index for children.

### WHAT CHILDREN ARE EATING NOW

The majority of the US population aged 1 year and older exceeds sodium intake recommendations, including more than 90% of children aged 4 to 18 years. In terms of absolute intake, mean sodium intakes were 191 mg/d for infants up to 6 months and 518 mg/d for those 6 to 12 months and 1709 mg/d for toddlers 1 to 2 years. Tigure 2 displays average sodium intake in

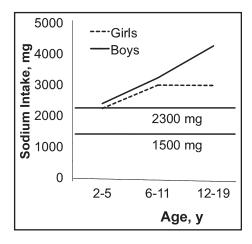


FIGURE 2. Mean sodium intake in US children by age group.<sup>51</sup>

older children and adolescents, which is remarkably similar to the high levels of intake in adults.<sup>38</sup> On average, children aged 2 to 19 years consume more than 3100 mg of sodium per day, with substantially greater sodium intakes in boys than girls. The mean sodium intake in boys, >4000 mg/d at ages 12 to 19 years, is particularly striking. This high intake, in part, reflects greater mean energy consumption in boys than girls.<sup>39</sup>

### **Dietary Sources**

Top contributors to sodium intake for birth through 2 years include formula (72%), human milk (23%), and commercial baby foods (2%). Store foods contributed 83% to 90% of sodium in this age group. For children aged 2 to 5 years, the top 10 sources of sodium include (in order) breads and rolls, poultry, frankfurters and sausages, soups, pizza, whole and reduced-fat milk, cheese, pasta mixed dishes, ready-to-eat cereal, and sandwiches. Close to half (43%) of sodium in school-aged (6–18 years) children's diets came from 10 similar food categories: pizza, bread and rolls, cold cuts/cured meats, savory snacks, sandwiches, cheese, chicken patties/nuggets/tenders, pasta mixed dishes, Mexican mixed dishes, and soups. The top six sources are illustrated in an American Heart Association infographic for children.

Among school-aged children, an average of 83% of sodium came from grocery store and restaurant foods (65% from store foods, 13% from fast-food/pizza restaurants, and 5% from other restaurants) and 9% from school cafeteria foods. By meal, children aged 6 to 18 years consume about 15% of their daily sodium at breakfast, 30% at lunch, 39% at dinner, and 16% at snack time.<sup>7</sup>

# ACCEPTABILITY OF REDUCED SODIUM FOODS

The development of flavor preferences appears to begin in utero and is presumably influenced by maternal diet; further food preferences initiated in childhood persist long-term. <sup>42–44</sup> Whether maternal sodium intake further influences the flavor of breastmilk and subsequent sodium preferences in childhood has yet to be established, but if

introduction to solid foods includes high-sodium choices, this can undermine adaptation to lower-sodium diets.

Attempts to achieve reductions in dietary sodium intake in children have most often targeted schools, <sup>29,30,45,46</sup> which offer an important setting to introduce and reinforce the benefits of lowering sodium intake. One early study in a boarding high school involved a cross-over design that not only achieved successful adherence to reduced sodium intake (based on 24-hour urine collection), but further reported an unwillingness among the students to return to the original sodium level typically served in the school after only 3 weeks on the lower-sodium diet.<sup>47</sup> This study illustrates the feasibility and acceptability of reducing dietary sodium intake among children if presented in an ongoing and consistent manner.

# FEASIBILITY OF SODIUM REDUCTION IN SCHOOL MEALS AND COMPETITIVE FOODS

The food industry has demonstrated progress in lowering sodium, and several major food companies are already offering products that meet the current school meals standards. Some of this progress has been achieved by simply reducing salt, with further reductions occurring as a result of innovation in food manufacturing technologies and culinary techniques. The broad variability of sodium content within similar food categories indicates that reduction to lower levels is feasible in at least some products. A recent survey showed a wide range of sodium content in the same branded foods across countries. Regional taste preferences may not be responsible for the variation in salt content, because no one country consistently had the highest-sodium products.

Taste is an important driver of food choices, but it is well-recognized that taste is a malleable trait. Although more sensory research would strengthen this conclusion, it is likely that children's preferences for salty foods will shift downward without loss of taste enjoyment if sodium in school meals is reduced in a gradual, stepwise fashion. Aided by technical assistance to help schools create meals that meet the sodium standards, the phased sodium reductions in the HHFKA are achievable.

The shift from Target 1 to Target 2 sodium levels in school lunches is approximately 300 mg per lunch across all grade levels, or 100 mg/y given that schools have three full school years to reduce from Target 1 to Target 2 levels. For reference, the amount of sodium in a single small pickle spear is approximately 300 mg. A reduction of 300 mg sodium per meal could also be achieved with a combination of food substitutions, such as using an unbreaded instead of a breaded chicken patty on a sandwich and seasoning rice with herbs and spices instead of salt. Additional suggestions for food substitutions are illustrated in an American Heart Association infographic.<sup>51</sup>

Leading contributors to sodium intake (such as pizza and breads/rolls) are also leading contributors to energy intake among children. Hence, strategies to reduce intake of these foods and/or replace them with lower-sodium versions or potassium-rich fruits and vegetables could have a positive impact on a spectrum of health issues, from elevated BP to childhood obesity. Furthermore, sodium reduction is not an isolated recommendation. It is an important component of a healthy dietary pattern exemplified by the nutrition standards described in the HHFKA. The foods that comprise the diets aligned with this pattern will not only have less sodium, but they are expected to have more potassium, magnesium, and calcium than standard American diets.

## CHALLENGES OF PREVENTION RESEARCH IN CHILDREN

Prevention research in children is challenging. In observational studies, it is difficult to accurately and precisely measure lifestyle factors related to diet and physical activity. This is particularly the case for sodium, 52 in which children or their adult proxies self-report dietary intake. The attendant result can be spuriously null findings, as recently reported.<sup>53</sup> Likewise, it is difficult to achieve a substantial contrast in dietary sodium intake in behavior intervention studies in children. Controlled feeding studies in children provide a powerful means to achieve a large experimental contrast but are logistically challenging, expensive, and inherently brief. Finally, trials with hard clinical outcomes are impossible to conduct in children, an issue common to all lifestyle interventions, not just sodium reduction. Indeed, there are no trials that have documented benefits of weight loss, smoking cessation, and increased physical activity on hard outcomes in children or even adults.

#### SUMMARY AND CONCLUSIONS

The antecedents of elevated BP and other chronic diseases begin early in life, as do food preferences. Given the vast scope of the hypertension epidemic and its adverse health consequences, the most appropriate approach to halt this epidemic should include prevention strategies that target children. Available data are sufficiently strong to recommend a reduced sodium intake as an effective and well-tolerated approach to lower BP. Indeed, findings that higher levels of BP are associated with subclinical target organ damage in childhood, track into adulthood, and predict adult subclinical target organ damage strongly support the need to implement strategies for reducing sodium intake in the first 2 decades of life. Rather than repealing public health efforts to lower sodium in school meals, we must redouble our efforts that ultimately should improve our children's health and the health of our nation.

#### References

 Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. *Circulation*. 2010;121:586–613.

- The School Breakfast Program. http://www.fns.usda.gov/sites/default/ files/SBPfactsheet.pdf. Accessed May 15, 2015.
- National School Lunch Program. http://www.fns.usda.gov/sites/ default/files/NSLPFactSheet.pdf. 2013. Accessed May 15, 2015.
- 4. Public Law 111–296. http://www.gpo.gov/fdsys/pkg/PLAW-111publ2 96/pdf/PLAW-111publ296.pdf. 2010 Accessed May 15, 2015.
- 5. Stallings VA, West Suitor C, Taylor CL. School Meals: Building Block for Healthy Children. Washington, DC: Institute of Medicine; 2010.
- McGuire S, Institute of Medicine. Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation. Washington, DC: The National Academies Press; 2012. Advances in Nutrition. 2012;3:708-709.
- School Nutrition Dietary Assessment Survey IV: Current state of school meals and snacks. http://www.mathematica-mpr.com/~/media/ publications/PDFs/nutrition/SNDA-IV\_Webinar\_13mar2013.pdf 2013. Accessed May 15. 2015.
- 2013. Accessed May 15, 2015.

  8. Rules Committee Print 113–59: Text of House amendment to the Senate amendment to H.R.83. 2014.
- Statement from Secretary Vilsack on New Data Showing the Vast Majority of Schools Now Meet the Updated Meals Standards; http:// www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=2015/05/0128.xml. In: USDA, ed2015. Accessed May 15, 2015.
- Turner L, Chaloupka FJ. Perceived reactions of elementary school students to changes in school lunches after implementation of the United States Department of Agriculture's new meals standards: minimal backlash, but rural and socioeconomic disparities exist. Child Obes. 2014;10:349–356.
- National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004;114(Suppl 4th Report):555–576.
- Vasan RS, Beiser A, Seshadri S, et al. Residual lifetime risk for developing hypertension in middle-aged women and men: the Framingham Heart Study. JAMA. 2002;287:1003–1010.
- Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. Circulation. 2008;117:3171–3180.
- Juhola J, Magnussen CG, Viikari JS, et al. Tracking of serum lipid levels, blood pressure, and body mass index from childhood to adulthood: the Cardiovascular Risk in Young Finns Study. *J Pediatr*. 2011;159:584–590.
- Lande MB, Carson NL, Roy J, Meagher CC. Effects of childhood primary hypertension on carotid intima media thickness: a matched controlled study. *Hypertension*. 2006;48:40–44.
- 16. Urbina EM, Khoury PR, McCoy C, et al. Cardiac and vascular consequences of pre-hypertension in youth. *J Clin Hypertens* (*Greenwich*). 2011;13:332–342.
- 17. Lurbe E, Torro I, Garcia-Vicent C, et al. Blood pressure and obesity exert independent influences on pulse wave velocity in youth. *Hypertension*. 2012;60:550–555.
- Falkner B, DeLoach S, Keith SW, Gidding SS. High risk blood pressure and obesity increase the risk for left ventricular hypertrophy in African-American adolescents. *J Pediatr*. 2013;162:94–100.
- 19. Berenson GS, Srinivasan SR, Bao W, et al. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med*. 1998;338:1650–1656.
- McGill HC Jr, McMahan CA, Gidding SS. Preventing heart disease in the 21st century: implications of the Pathobiological Determinants of Atherosclerosis in Youth (PDAY) study. Circulation. 2008;117:1216– 1227.
- 21. Juonala M, Magnussen CG, Venn A, et al. Influence of age on associations between childhood risk factors and carotid intima-media thickness in adulthood: the Cardiovascular Risk in Young Finns Study, the Childhood Determinants of Adult Health Study, the Bogalusa Heart Study, and the Muscatine Study for the International Childhood Cardiovascular Cohort (i3C) Consortium. Circulation. 2010;122:2514–2520.
- 22. Aatola H, Magnussen CG, Koivistoinen T, et al. Simplified definitions of elevated pediatric blood pressure and high adult arterial stiffness. *Pediatrics*. 2013;132:e70–e76.
- Hartiala O, Magnussen CG, Kajander S, et al. Adolescence risk factors are predictive of coronary artery calcification at middle age: the cardiovascular risk in young Finns study. *J Am Coll Cardiol*. 2012;60:1364–1370.
- Mahoney LT, Burns TL, Stanford W, et al. Coronary risk factors measured in childhood and young adult life are associated with

- coronary artery calcification in young adults: the Muscatine Study. J Am Coll Cardiol. 1996;27:277-284.
- Juhola J, Magnussen CG, Berenson GS, et al. Combined effects of child and adult elevated blood pressure on subclinical atherosclerosis: the International Childhood Cardiovascular Cohort Consortium. Circulation, 2013:128:217-224.
- 26. He FJ, MacGregor GA. Importance of salt in determining blood pressure in children: meta-analysis of controlled trials. Hypertension. 2006;48:861–869.
- 27. Hofman A, Hazebroek A, Valkenburg HA. A randomized trial of sodium intake and blood pressure in newborn infants. JAMA. 1983;250:370-373.
- 28. Geleijnse JM, Hofman A, Witteman JC, et al. Long-term effects of neonatal sodium restriction on blood pressure. Hypertension. 1997;29:913-917.
- 29. Ellison RC, Capper AL, Stephenson WP, et al. Effects on blood pressure of a decrease in sodium use in institutional food preparation: the Exeter-Andover Project. *J Clin Epidemiol*. 1989;42:201–208.

  30. He FJ, Wu Y, Feng XX, et al. School based education programme to
- reduce salt intake in children and their families (School-EduSalt): cluster randomised controlled trial. BMJ. 2015;350:h770.
- 31. Sinaiko AR, Gomez-Marin O, Prineas RJ. Effect of low sodium diet or potassium supplementation on adolescent blood pressure. Hypertension. 1993;21(Pt 2):989–994.
- Yang QH, Zhang ZF, Kuklina EV, et al. Sodium intake and blood pres-
- sure among US children and adolescents. *Pediatrics*. 2012;130:611–619.
  33. Institute of Medicine. *Dietary Reference Intakes for Water, Potas*sium, Sodium, Chloride, and Sulfate. Washington, DC: DC National Academies Press; 2005.
- Dietary Guidelines Advisory Committee. Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans 2010. Springfield, VA: National Technical Information Service; 2010.
- 35. Centers for Disease Control and Prevention. Usual sodium intakes compared with current dietary guidelines - United States, 2005-2008. MMWR Morb Mortal Wkly Rep. 2011;60:1413-1417.
- Dietary Guidelines Advisory Committee. Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Washington, DC: Dietary Guidelines Advisory Committee; 2015.
- Carriquiry A, Moshfegh AJ, Steinfeldt LC, et al. Trends in the prevalence of excess dietary sodium intake – United States, 2003–2010. MMWR Morb Mortal Wkly Rep. 2013;62:1021–1025. What We Eat In America, NHANES 2011–2012 http://www.ars.us-
- da.gov/SP2UserFiles/Place/80400530/pdf/1112/Table\_1\_NIN\_GEN\_ 11.pdf. In: USDA, ed2011–2012. Accessed May 15, 2015.

- 39. Cogswell ME, Yuan K, Gunn JP, et al. Vital signs: sodium intake among U.S. school-aged children - 2009-2010. MMWR Morb Mortal Wkly Rep. 2014;63:789-797.
- US Department of Agriculture ARS. Nutrient Intake from Food and Beverages: Mean Amount Consumed per Individual, by Gender and Age, What We Eat in America, NHANES 2011-2012. Beltsville, MD: ARS (Agricultural Research Service) Food Surveys Research Group; 2014.
- The Salty Six for Kids, www.heart.org/sodiuminfographics.
- 42. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. Pediatrics. 1998;101(Pt 2):539-549.
- Mennella JA, Jagnow CP, Beauchamp GK. Prenatal and postnatal flavor learning by human infants. Pediatrics. 2001;107:E88.
- Skinner JD, Carruth BR, Wendy B, Ziegler PJ. Children's food preferences: a longitudinal analysis. J Am Diet Assoc. 2002;102:1638–1647.
- 45. Howe PR, Cobiac L, Smith RM. Lack of effect of short-term changes in sodium intake on blood pressure in adolescent schoolchildren. J Hypertens. 1991;9:181–186.
- 46. Howe PRCJK, Smith RM. Sodium and blood pressure in children a short-term dietary intervention study. Proc Nutr Soc Aust. 1985;10:121-124.
- 47. Cooper R, Van Horn L, Liu K, et al. A randomized trial on the effect of decreased dietary sodium intake on blood pressure in adolescents. Hypertens. 1984;2:361–366.
- 48. National Alliance for Nutrition and Activity, Mission: Possible -Companies Can Meet the USDA's New Sodium Limits for School Meals. Fact sheet. 2014.
- 49. Antman EM, Appel LJ, Balentine D, et al. Stakeholder discussion to reduce population-wide sodium intake and decrease sodium in the food supply: a conference report from the American Heart Association Sodium Conference 2013 Planning Group. Circulation. 2014;129: e660-e679.
- World Action on Salt and Health, New Study Reveals Huge Differences in Salt Levels in the Same Iconic Food Brands in Different Countries. http://www.worldactiononsalt.com/less/surveys/2014/141 133.html. Accessed October 16, 2014.
- 51. American Heart Association. Lower Sodium in School Foods. http:// www.heart.org/idc/groups/heart-public/@wcm/@adv/documents/down loadable/ucm\_472940.pdf. 2015. Accessed May 15, 2015.
- 52. Cobb LK, Anderson CA, Elliott P, et al. Methodological issues in cohort studies that relate sodium intake to cardiovascular disease outcomes: a science advisory from the American Heart Association. Circulation, 2014;129:1173-1186.
- 53. Buendia JR, Bradlee ML, Daniels SR, et al. Longitudinal effects of dietary sodium and potassium on blood pressure in adolescent girls. JAMA Pediatr. 2015;169:560-568.